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COURSE IN BIOLOGY

IN THE

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ANNOUNCEMENT OF VOLUME II — 1901

No. 1 January — *The Course in Biology in the Horace Mann High School*, with chapters on the aim and methods of teaching Botany and Zoölogy. — Professor F. E. LLOYD and Mr. M. A. BIGELOW.

The following numbers in preparation:

Geography in the Horace Mann School. — Professor R. E. DODGE.

Child Study. — Sources of Materials and Syllabi of College Courses. — DR. E. L. THORNDIKE.

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TEACHERS COLLEGE RECORD

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COURSE IN BIOLOGY IN THE HORACE MANN SCHOOL[1]

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Preface

The courses in botany and zoölogy here presented in outline are given in the first year in the Horace Mann High School, and are followed by the courses in physics and chemistry. It is still a question whether this arrangement is the best. It has been argued by some that botany and zoölogy should come later in the high-school course for the reason that a knowledge of chemistry and physics is necessary to any understanding of the physiology of plants and animals. And this cannot be doubted. But, on the other hand, experience has shown that even when biology has been placed later in the high-school course, preceded by chemistry and physics, only a portion of the class are sufficiently familiar with those sciences to obviate a repetition of the principles in connection with their application in the biological laboratory. So far as any distinct advantage accruing to the student or teacher is concerned, therefore, the conditions are but little different from those obtaining under the present arrangement in the Horace Mann School, under which some of the pupils enter the class from the elementary school with a slight elementary knowledge of chemistry and physics, and others with none. In either case the problem of presenting the subject of biology is much the same.

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Over against the argument based on the logical sequence of the sciences is one derived from interest. It appears to be a pretty widely recognized fact that natural history generally appeals much more strongly to students of the earlier years of the high school than to those of the later years. Just why this is so need not be discussed here. This order, however, finds support in the action of the National Educational Association taken at the meeting of 1899, at which time that body took action upon the question of the order of sciences in the high-school curriculum. It may with justice be added that the plan here described was decided upon before the conclusion of that body was reached.

Four forty-five-minute periods are given each week to the work, an amount of time deemed somewhat too brief. The zoölogical part of the course is given in the first half-year, followed by the botany in the second half-year. This arrangement appears to be justified by two considerations. First, the materials for botanical work are more available on the whole in the spring than in the autumn; more especially those used in Part 2 of the course in botany, which deals with classification in a broad sense, and with ecology. Second, it would appear that the study of animals is taken up rather more eagerly by young pupils — that is of the age of twelve or fourteen — than that of plants, for the possible reason that the responses of animals are more pronounced, but more probably because the knowledge which they gain appears to them to touch their own lives more immediately. Experimentation on plants and observation of them by young students require rather more prolonged and patient attention — a kind of work which is done better after some training in biological method has been received.

The objects of the course in biology are to give training in the use of the scientific method of thought in general, more especially as applied to the study of living organisms; and to develop in the mind of the student a fair idea of the subject matter of biology, and of the economic importance of animals and plants. In attaining these more immediate ends it is expected that further results will be secured, namely the development of intelligent citizens versed in the proper ways of thinking about the organic creation and appreciative of the value of scientific effort for the amelioration of the conditions of human life.

Looking toward the attainment of the above ends, it is intended in this course to give a share of attention to the form and structure of living organisms, to their development and relationships, to their physiology and ecology, and, finally, to their economic importance. As a result of this method of treatment the student should get considerable knowledge of the appearance of many forms, and some limited information of internal structure. He should get at the same time the very important idea that the living organism is carrying on various physiological operations, that reaction between organism and environment is constantly taking place, that organisms are essentially adaptive, and that in both animals and plants there is an essential similarity to be expressed in terms of general biology. Finally, the student should get a definite knowledge of some ways in which organisms contribute to the well-being and happiness of the human race as a result of the intelligent use which man has made of them.

A brief study of the outline will show a general similarity in the two parts of the course. In each course some time is given at the beginning to a careful study of fundamental principles in preparation for an intelligent appreciation of what follows. One part, therefore, is conducted intensively; another part is less exacting as to detail, and is designed to meet the view-point of modern natural history. It should also be added that the spirit and method of the work is the same in both courses, allowing, of course, for the individuality of the instructors.

Each course is also complementary to the other. In the outline of the study of plants, for example, no specific attention is paid to the cell. This has been done already in the zoölogical part of the work, and does not need to be repeated formally when the cell is taken up in the study of the digestion, absorption and transformation of food.

A course of this kind, then, may fairly be said to justify the application of the name of General Biology to it, and as such it is claimed to possess the unity and comprehensiveness which that name demands. Little or no attempt has been made to display this in the outlines themselves, for unity, correlation and like qualities appear in the spirit and immediate treatment of the work rather than in the form.

A further point calls for mention here. The method of beginning the study of biology with the simple forms of life, and pro-

ceeding to the complex, the so-called logical method, has found no support in the Horace Mann School. The assumption that the young mind places the same value upon a given logical arrangement of scientific facts as the more mature mind, is, we believe, an educational fallacy which is refuted by the experience of many able and thoughtful teachers. For this reason, therefore, the logical method has been abandoned in favor of a method both psychological and practical.

F. E. L.
M. A. B.

The Course in Zoölogy

By MAURICE A. BIGELOW

A. INTRODUCTION

The accompanying outline of a course in elementary zoölogy will, perhaps, be better understood if prefaced by some discussion of the aims and of certain propositions which underlie the course.

In the opinion of the writer the various aims which have been suggested by authors on elementary zoölogy may be conveniently classified into two groups. In the first group may be classed all aims which have a direct reference to scientific training; while in the second may be included all aims relating to the acquirement of knowledge of the subject matter.

The aims in the first group, stated in a general way, have reference to the development of a scientific attitude of mind, by directing various mental processes, such as scientific observing, reasoning on the basis of demonstrated facts, exercising judgment and discrimination, and learning to appreciate demonstrated knowledge. This is not the place to attempt a complete analysis of the attitude of mind which characterizes the student of science. Enough has been said to indicate the general direction of the first group of aims. The importance of the training which this involves has long been recognized, and the discussion need not be renewed here.

It is evident in the form of the statement that the aims of the first group are not advocated as peculiar to zoölogy. It is now well recognized that all of the sciences furnish materials for developing the chief elements of the general scientific attitude

of mind. The writer accepts the opinion of many teachers that in the teaching of every science in a secondary school it should be borne in mind that, since few pupils have opportunities for the thorough study of several sciences, no occasion should be neglected for giving training in scientific observing and scientific thinking. Many educators regard such training as far more important in liberal education than the knowledge of the facts of any science. However, it is not necessary in teaching a science with scientific training as one leading aim that its essential facts should be neglected, for the training depends largely upon the method of teaching rather than upon the subject matter. The realization of these aims is found in the general method of modern science — the laboratory method; but the quality of the training depends upon the way in which the laboratory work is directed. If the aims of the first group are to meet with the greatest possible realization, it is necessary that they be kept in mind while planning a laboratory course in zoölogy, for very much depends upon the manner in which problems for solution are presented to the minds of the pupils.

Aside from the training in mental processes which the study of zoölogy may give the pupil, there is an important phase in which zoölogy stands upon its own merits as a science with subject matter, some knowledge of which is believed to form a valuable part of liberal education. The second group of aims — second only in order of statement — is concerned with the acquirement of important facts and ideas of zoölogy.

In selecting the subject matter for an elementary course in zoölogy for secondary schools, the field of zoölogical knowledge should be viewed from the standpoint of liberal education, as distinguished from special or technical education. The field is wide, and at best only a glimpse of animal structure and life can be given in a single course. Bearing in mind that the great majority of secondary pupils can never follow more than one course of instruction in the subject, the problem is to fill that one course with those zoölogical facts and ideas which have the closest relation to the every-day life of a liberally educated man. In the future it should be recognized more clearly than in the past that many phases of the science of zoölogy, which are of interest and importance to the specialist, may have no definite meaning to a man in other walks of life. Many teachers of zoölogy in secondary

schools do not seem to have examined the subject in this light, and as a result elementary zoölogy has been too often taught as if it were the aim to train the pupils for professional work in zoölogy or in some of its direct applications, such as medicine. This special or technical training is the proper work of colleges, and has no more place in the secondary school than have higher applied mathematics.

The wide difference between the aims which govern the zoölogical teaching in colleges and those which should underlie the work in the secondary school needs to be emphasized, for already there have been too many attempts to transfer college courses and books into the secondary school. It is not a question of how near an approach can be made to the college introductory courses in zoölogy, but a question of the value of such work in liberal secondary education. Is it the most valuable which can be selected from the wide field of zoölogy? This is the really vital question which apparently has been asked by few of those who have prepared outlines of study for elementary zoölogy in secondary schools.

The course in elementary zoölogy which in the past decade has been followed in the majority of schools consists largely of detailed comparative study of the anatomy of a series of animals. It is a very close imitation of a common introductory course for college students. Several published books well represent this morphological course, and one who examines carefully is forced to conclude that very much of the subject matter is so technical and detailed as to be of very doubtful value to a liberally educated man who has no special reason for being learned in zoölogical science. In such a course there is no time for the pupil to learn anything about the life of animals or even the existence of many important animals, and, as usually conducted with preserved specimens, it is far from being a study of animal life. It is evident that the course under discussion will give pupils who follow it an extremely narrow view of the animal kingdom in its varied aspects.

The introductory college course in zoölogy from the morphological standpoint is usually followed by other courses in which other phases of zoölogy are considered, and in the end the students may gain a broad view of the field of zoölogy, and learn to think of animals in the various aspects of their structural and

functional relations. In the college system the student is expected to acquire much technical information while he is getting a general view of the field of zoölogy. In the secondary school the technical matter is undesirable, but the general view is of great importance, and in one short course within a single year (usually a half-year) must be included all that the majority of pupils are ever to be taught about animals. Are we not justified in concluding that an isolated course from the standpoint of comparative anatomy, while perhaps well adapted to the college system, fails to give the wide view of animals which is desirable in liberal education, and, therefore, does not meet the needs of the majority of secondary pupils?

It is now sometimes urged in defense of the course in anatomy that the working out of details of structure tends to give valuable scientific training. But much of this is purely special training, and the facts of detail are only of technical value. There is a growing belief among naturalists that much of the anatomical study in secondary courses can be replaced with more important subject matter, and this with no loss so far as efficiency in developing scientific observing and thinking is concerned.

In so far as it deals with the great facts of animal structure, the anatomical course has many good features which commend it for secondary education; but in so far as stress is placed upon details and comparisons of number, minute structure, exact extent and position of organs in some half dozen types of animals, the study must be regarded not only as of little importance in liberal secondary education, but also as using time which should be devoted to undoubtedly more important phases of zoölogical study. But since the study of general anatomical structure is important as giving a basis for other phases of zoölogical study, therefore it is necessary that this much of the morphological course should be retained.

Within recent years there has been a reaction and a decided tendency towards abandoning many of the characteristic features of the morphological course, and returning towards the old-time natural history course. This reaction is best expressed by the recent *Introduction to Zoölogy* by Davenport. Such a course, as usually presented, has little or nothing to do with the study of internal structures of animals, and consequently there can be no scientific consideration of the fundamental physiological processes.

Emphasis is placed on study of external form, classification, movements, habitats and life histories of animals. Such studies of animal life and its relations are especially valuable in preparation for college courses which are largely composed of those phases of zoölogy which have little concern with natural history. The college and secondary courses under such a system would be supplementary with no repetition, and in the end those students who take both college and secondary courses in zoölogy may have a broad view of animal structure, function and life. There can be little doubt that the course in natural history is valuable in preparation for the more advanced work in the college, but it may well be doubted whether such a course is altogether the best for secondary work when considered from the standpoint of liberal education. In the omission of all reference to the general facts of internal structure and functions, has not the reaction from the purely morphological course been too extreme?

In secondary work the important physiological side of zoölogy has received but little attention, as compared with that given to natural history and morphology. In the types of elementary courses which have been discussed, there is often some mention of comparative physiology, or some observational work on responses to external stimuli; but, on the whole, physiology can hardly be considered as one of the characteristic features in the usual examples of either of the two types of courses. The fundamental physiological relations of the internal machine of the animal body have been neglected almost universally, but they should be as characteristic as any other feature of an elementary course.

The importance of interpreting the activities of the human body from the comparative standpoint seems sufficient reason for advocating the consideration of the fundamental principles of physiological action in connection with the study of elementary zoölogy. Experience has convinced the writer that there is no more profitable study for secondary pupils than the physiological side of animals. No other phase of zoölogical study arouses a deeper interest and appreciation or is more spontaneously applied by the pupils in connection with study of their own life activities. It is scarcely necessary to offer a stronger reason for including such study in an elementary course.

Summarizing the review of the ordinary types of courses in

elementary zoölogy, we must recognize that there are important features in both the morphological and the natural history courses, but when standing alone each is extreme. Each has fundamental facts and ideas which are of interest in liberal education, and also in each there are numerous details which have only special or technical value. From this follows the suggestion that the essential and valuable features of the two courses may be selected and incorporated into one. But this is not sufficient, for it has been pointed out that the very important physiological side of zoölogy deserves attention, which neither of the ordinary courses gives. The course, then, which will meet the demands of liberal education should be a study of animals from the combined aspects of the fundamentals of morphology, physiology and natural history. This statement must not be misinterpreted. To a naturalist each of the three fields is much too wide even for a lifelong study, but it must be kept in mind that the problem in secondary work is to give the pupils the most valuable ideas of animals, and the widest view of animal life. The demand of liberal education is for a broad attitude of mind towards animals, and good general ideas of the fundamentals of zoölogy. The vast masses of facts of detail which interest the naturalist must be reserved for special study by those who have time and special reasons for advanced study of the science.

Among the minor problems involved in arranging a course combining the essentials of the various phases of zoölogy, the first and most difficult one is concerned with the inclusion of physiological work in the course in elementary zoölogy. By physiological the reference here is directly to the essential processes in the general metabolism of the animal body, and the term is not limited to the mere work of observing a few movements and responses to stimuli which constitutes the great part of the so-called physiological study in many elementary courses. The study of fundamental physiological processes obviously admits of very little practical work in a direct line,.and the facts must be presented by text-book and teacher. But the morphological basis for such can be strictly practical, and a logical presentation should lead the pupils from observed facts to conclusions, so that the discussion of the subject of general physiology of animals may be of far more value than a mere didactic exercise.

The usual objection to physiological work in secondary

schools is that the subject cannot be presented by a strictly laboratory method. But how much physiology does the advanced student get directly from his own laboratory studies, as compared with what he accepts on the authority of teacher and books? In how many colleges is the laboratory method *strictly* and *exclusively* applied in biological teaching? The evident answer to these questions shows how weak is the argument that only strictly practical work should be included in elementary zoölogy in secondary schools.

In combining physiology with the morphological work of the course in zoölogy, it is important that the two phases of study be closely related throughout the course. The few text-books and teachers' outlines which merely suggest the tendency towards a union of the two phases of zoölogical study seem to show that in general the attempt is to teach physiological ideas in the form of abstract generalizations with little of concrete application to particular animals which are studied morphologically. Sometimes these generalized principles of physiology are introduced before the pupils have progressed far in the practical study of animal strucure, but more often after the completion of a purely morphological course. The latter is the case in a recent and in many respects commendable text-book and manual of elementary zoölogy by Kingsley, in the last chapter of which there is an excellent statement of the principles of comparative physiology, but there is no specific concrete application of those principles. Such a method of presenting the principles apart from concrete application is open to serious objection. In the light of experience it may well be doubted whether such presentation gives secondary pupils a clear conception of general life-activities. A physiological principle may be formulated in a generalized way, and as such may be memorized by the pupils; but that they do not grasp the ideas involved is shown by the fact that they usually fail in application when concrete cases are placed before them. Every zoölogist knows in personal experience how indefinite and unsatisfactory are the ideas gained from reading generalizations if he cannot easily recall and connect them with the specific underlying facts. In order to appreciate the attitude of the elementary pupil, it is only necessary to recognize the fact that even at the close of a half-year course the pupil has not the definite remembrance of the details of structure which are neces-

sary for concrete illustration and application of the principles of physiology. In order to give the clearest possible conception of physiological principles it is essential that structures and functions should be studied in their natural relations. The principles of physiology should be introduced with the first animal which is studied morphologically, and each principle as introduced should receive concrete application. The study can easily and quickly be made comparative as successive types of animals are taken up, and finally such specific and comparative studies may be made to lead to a direct application of the principles of comparative physiology to the activities of the human body.

Another minor but important problem which demands consideration is the much discussed question regarding the value of unicellular versus multicellular animals as types for the introductory study. Shall a course in elementary zoölogy be synthetical, beginning with unicellular animals and then progressing towards the more and more complex forms, or shall the study be analytical and, beginning with a complex multicellular animal, lead down the scale of structural and functional complexity to the simplest forms? The first named order is the one usually followed, and it is defended chiefly on the ground that it corresponds with the logical order in the development of complexity in the animal series. However much weight this may have in college work, it is doubtful whether the generalizations involved in considering animal structure and function synthetically are grasped by immature beginners in secondary schools. Moreover, an appreciation of the relations underlying the great idea of organic evolution does not necessarily depend upon a study of animals taken in the order of increasing complexity. It appears then that the argument for logical order must be regarded as insufficient.

The difficulties involved in an attempt to grasp the meaning of the structure of a protozoön are greatly complicated by the still greater difficulties which confront the beginner with the compound microscope. By use of the microscope is not meant mere mechanical manipulation, but especially accurate interpretation — a far more difficult thing for most beginners. Very many teachers consider this alone sufficient reason for *not* beginning the course of study with a microscopic form, for if the introductory type is a multicellular form of considerable size, the

use of the microscope can be learned gradually in connection with the gross examination.

The advantages of beginning the study of structure with an animal about which the pupil knows something, or at least can learn with the aid of no more uncommon apparatus than the eyes, were well stated by Huxley many years ago after he had learned by experience the great disadvantages connected with beginning zoölogical study with a microscopic animal. Many teachers in colleges have since expressed agreement with this opinion of Huxley. As applied to elementary zoölogy in secondary schools where the pupils are undeveloped, the arguments advanced by Huxley are of greater weight than when applied to college work. Pupils encounter few serious difficulties in an introductory study of the important points of structure in a complex animal. The supposed difficulties arise largely when detailed study is attempted. The general relations and the *essential* structure of organs are in the very beginning readily determined and comprehended by very young pupils.

The same arguments hold good from the physiological point of view. Every pupil knows something about the functions of his own body, and it is easy to grasp the fundamental principles of physiology when concretely applied to organs of an animal in which there is considerable physiological division of labor. It is evident that this must be a decided gain when compared with beginning physiology with a unicellular animal where all functions must be thought of abstractly in connection with a single cell. Beginning with the physiology of a multicellular animal, and considering a series of simpler forms which lead down the scale in division of labor, the pupils can understand every step of the way, and in the end will have a clearer idea of the functions of both one- and many-celled forms in their relation to the great principle of physiological division of labor.

The conclusion must be that so far as the work of secondary schools is concerned there is very little to be said in favor of introducing the course in elementary zoölogy by study of a unicellular animal, while there is much in favor of beginning with the multicellular form. The simplest animals appear to be, after all, the most complex from the young beginner's standpoint. More than this, almost everything which is supposed to argue for a logical and synthetical order of study depends upon gen-

eralizations which are not appreciated by the average secondary pupil. The experience of large numbers of teachers seems to support strongly such conclusions.

In preceding paragraphs it has been advocated that elementary zoölogy should include the most important facts and ideas of general anatomy, natural history, and the essentials of physiology. It has also been urged that physiological study should be intimately associated with morphological study from the very beginning of the course. Finally, reasons have been given for regarding multicellular animals as most favorable for introductory work which is to involve any of the above aspects of zoölogy.

Depending directly upon the foregoing conclusions, the central idea of the course in elementary zoölogy which is outlined in this paper is that of an introductory study of a complex animal examined from the several view-points of zoölogy. Such a study includes the most important facts of anatomy, histology, embryology, classification in connection with the near allies of the introductory type, distribution and ecology, general fundamental principles of physiology, habits of life, and life history. Again it may be necessary to remind the reader that this is not to be misunderstood as meaning that any one of these phases of study should go far into details. The question — What is essential for liberal education? — should be strictly applied in eliminating all that has no good reason for inclusion in the course. The writer's interpretation of what may be considered valuable in this connection will be best represented by a detailed outline of such an introductory study of one animal, and this is given in the outline of the course.

This method of introducing the study of zoölogy by a broad biological study of a single animal has long been favorably received in college work. It is unnecessary to show here that the important facts of animal structure and function can be well presented and illustrated by study of a single animal. Huxley's classical work on the crayfish, as an introduction to the study of zoölogy, gives sufficient defense of this method; and Sedgwick and Wilson have successfully applied the same idea to the earthworm. These two books have suggested the line of work which is here advocated for elementary zoölogy. Both the work of Huxley and that of Sedgwick and Wilson are far too advanced and technical for elementary pupils, but it will appear in the

general plan of the outline that these books have contributed many suggestions.

Such introductory study as has been suggested can be completed within the first five weeks of a half-year course, leaving eleven or twelve weeks in which to take a broad survey of the animal kingdom. This will be criticised on the ground that it gives too much attention to a single animal; but it will appear in the outline that most of this time is devoted to zoölogical principles capable of wide application, and which are illustrated by the careful study of a single animal. After pupils once grasp these principles, application to animals which are studied later is easily and quickly made. This method of introducing the study is designed to give pupils general ideas of the structure and activities of one animal which will aid in appreciating and interpreting any other animal. It is also intended to give intensive study of the fundamental principles of anatomy and physiology, and thus lay a foundation for a deeper acquaintance with many other animals representing important groups. Accepting the view of those naturalists who consider studies in natural history very important in liberal education, the aim is to prepare for them by including in the introductory work many of the most important topics from the other phases of zoölogy, so as to give a broader view of animals and their life than natural history alone can give. In short, the general aim is to lay a foundation which will make later study of animals, from whatever standpoint, more interesting and more intelligible, because there is included in the foundation work those great principles of animal structure and function which are of wide interest and application.

The writer is convinced that the broad view of a single animal and of some of the general principles of zoölogy, gained from the introductory study, exert a marked influence on all subsequent study of animals. Pupils with such preliminary training may be required later to study some animals from a limited point of view, for example, natural history or morphology, but their general ideas of one animal from the various points of view lead them to think of all animals as presenting illustrations of the various aspects of zoölogy. The pupils, as a rule, are eager to study every animal brought into the course as thoroughly as the introductory type was studied — that is, from the various aspects of zoölogy. Although time will not allow such extensive study

of more than one form, there is great value in such an attitude of mind with its broad outlook and interest in the various phases of animal life. This fact is mentioned here partly for the purpose of showing that interest is not lost by extended introductory work, as some critics have already urged on *a priori* grounds. Experience indicates that there is a gain rather than a loss in interest.

In conclusion it is claimed that upon a broad introductory study of one multicellular animal it is possible to base a course which combines the most valuable features of the various courses usually presented in secondary schools, and that it is possible at the same time to give as good training in scientific observing and thinking as can be done with any other course. Moreover, such a course gives a view of animals and animal life which is broader and more valuable from the standpoint of liberal education than that given by the ordinary courses which are limited to the viewpoints of either natural history or morphology. This claim is based upon the fact that such a course includes the fundamental principles of physiology in the natural relations with morphology and natural history, the importance of which relation has been discussed elsewhere.

It is not claimed that pupils who follow such a course know much about the details of comparative anatomy in a series of animals, or understand the intricacies of physiological processes, or that they store up a mass of facts from natural history; but from the standpoint of liberal secondary education stores of facts are not needed so much as broad general ideas, and an acquaintance with and interest in animals and their life.

In the preceding part of this paper there have been discussed the various problems considered during the development of the course in elementary zoölogy, which has been presented this year (1899-1900) to the first-year class in the Horace Mann High School, and which has also been outlined and discussed before the class in methods of teaching biology in secondary schools (Education 12). The course was not introduced into Teachers College as an experiment, for in its general outlines it was planned and introduced into a western academy in 1896. The general plan then proved satisfactory and has been in process of development since that year. Anticipating the objection that such a course is utterly inapplicable to the average public high school, it may be

said that in the above mentioned academy the conditions — numbers of pupils, equipment, time and development of pupils — corresponded quite closely with those of high schools; and also that the general plan of the introductory study has been tried at the writer's suggestion in a typical western high school and found satisfactory.

B. OUTLINE OF THE COURSE IN ZOÖLOGY

I. A Study of the Crayfish[1] *as an Introduction to the Study of Animals*

(Five weeks)

1. General External Structure of the Crayfish

(All topics preceded by an asterisk * are considered in lectures, readings and recitations, which are held in close relation with the corresponding laboratory work.[2])

General form of body, head, thorax, abdomen, appendages. Identification of anterior, posterior, dorsal, ventral, longitudinal and median, and bilateral symmetry of this and other familiar animals. Segments of the body. Skeleton. *Moulting, specimens exhibited. Outline drawings from dorsal, lateral and ventral views, labelling the chief structures represented.

Examination of the gills, attachment, number. Structure of a gill. Examine animals in which carmine has been forced to the gills from the heart and blood vessels. Drawing of animal showing position of the gills.

Examination of appendages and comparison of Appendages V to XIII and the abdominal appendages (drawings). *The principle of homology.

*Automatic amputation of appendages and regeneration, with demonstrations.

Examine lobster, prawn and crabs. In tabular form record comparisons with the crayfish. General characters of decapod crustacea. *Principles of classification. *Scientific names of animals — nomenclature. *Species, genera, orders, illustrated by decapod crustacea.

[1] The reasons for using the crayfish as an introductory type are set forth in Appendix A.

[2] Some minor methods of directing the laboratory and supplemental work are outlined in Appendix B.

Study of the living crayfish, movements, habits of life, senses.[1] Uses of the appendages, compare with the crab. Adaptations.

*Natural history. *Economic importance. *Distribution shown by colored map. *Fossil crayfishes.

Composition of 200 to 300 words on the external structure of crayfish compared with the other decapods examined.

2. General Internal Structure

Examination of a series of dissected specimens.

a. Specimens 1 and 2. Carapace removed. The exposed organs of male and female crayfish examined and drawn as seen in position.

b. Specimen 3. Carapace and dorsa of abdominal segments removed. Blood system injected with carmine. Heart and dorsal arteries examined and drawn with the other organs as seen in position.

c. Specimens 4 and 5. Carapace and heart removed. Reproductive organs in male and female. Ducts on one side dissected out. Drawings of organs as seen in position.

d. Specimen 6. Dissected to show digestive system. Drawing from dorsal and lateral views. Examine internal structure of alimentary canal and connection with the "liver."

e. Specimen 7. Dissected to illustrate muscular system. Carapace, dorsa of abdomen, stomach, heart, reproductive organs and "liver" removed. Examination of dorsal and ventral longitudinal muscles. Observe

[1] Within the limits of this outline it is impossible to specify in detail concerning the studies of the living crayfish and other animals. It should be mentioned that those experiments which give uncertain results, especially those leading to anthropomorphic interpretations, are avoided, or at least great care is taken to guard against wrong conclusions. One illustration will make this clear; for example, in the much abused experiment to test the sense of hearing in the crayfish the possibility that the reaction is produced by ordinary vibrations aside from sound waves is explained to the pupils. Similarily in experiments on taste and smell it is necessary to criticise severely results obtained by the use of irritants, such as ammonia, clove oil and like substances which authors recommend.

movement of abdomen of living animal, and compare with the arrangement of the body-muscles. Examine muscles of the great claws. Diagrams.

f. Specimen 8. Dissected to show excretory and nervous systems. Drawings of organs as seen in position. Demonstration of preparations of the nervous system, showing general method of distribution of nerves to organs.

g. Reference to the various dissections and drawings and construction of diagrams showing the relative position of organs in imaginary sagittal plane, and also in transverse planes through the heart and abdomen.

NOTE. — This exercise is designed to give practice in visualizing geometrical relations.

h. Tabulation of organs of the crayfish according to the systems of functions.

3. INTRODUCTORY MICROSCOPIC WORK AND ELEMENTARY HISTOLOGY

NOTE. — At this stage the pupils are introduced to the microscope, and, after examination of the instrument, practice with low powers is given. Most of the preparations mentioned below, which require high powers, are arranged by the instructor, and, after explanation by diagrams, the preparations are examined by the pupils, and drawings made.

Examination of preparations from various organs — liver, gill, intestine, muscle. (The aim here is to give some general ideas of tissues and cells; nothing in the line of formal histology is intended.)

*Organs, tissues and cells in animal structures. *Protoplasm.

4. ELEMENTARY EMBRYOLOGICAL STUDY

Demonstrations of preparations of the ovary and spermary of crayfish or other animal, illustrating the cellular nature of the germ-cells. Demonstration of preparations, showing pronuclei approaching and united. *Fertilization. Preparations showing three phases of mitosis in first and second cleavages in any favorable egg (drawings). *Cell division. *Cells in development and growth of animals.

NOTE. — Fertilization and cell-division are better illustrated by preparations from animals other than the crayfish. At various times such materials as starfish, sea-urchin, barnacle and mollusk eggs have been used in this connection and found satisfactory.

In the description of cytological structures and processes the attempt is to avoid the intricacies of centrosomes, chromosomes, etc.

Examine a crayfish, lobster or prawn with eggs attached to the appendages. Examine and draw stages in the development of the crayfish or lobster.

5. *GENERAL PRINCIPLES OF ANIMAL PHYSIOLOGY AS ILLUSTRATED BY THE CRAYFISH[1]

Movements and the muscular work of the body. Source of the energy thus manifested. Statement of the law of conservation of energy and familiar applications. Oxidation in liberation of energy, and illustrations. Foods as sources of energy. The need of oxygen. Waste, repair and growth of the body.

The stages of nutrition and the *essential* processes involved in each — digestion, absorption, circulation, assimilation, respiration, dissimilation, excretion. Special attention is given to the idea that physiological processes are ultimately referable to the component cells of organs; and also emphasis is placed on the consideration of each process as related to the life of the body as a whole, that is, to general nutrition. Finally, the nervous system is considered as a regulating and coördinating mechanism.

Physiological division of labor in the crayfish. Illustrations of the principle as shown by specialization in human social organization. (No reference is made to lower forms of animal life until they are studied.)

*Relation of the crayfish to its environment — Ecology.

*Animals in their relation to plants in the ultimate food supply.

[1] The general trend of the discussion of topics in physiology follows that of Chapters 8, 9 and 10 in Martin's *The Human Body*, Briefer Course (Revised Edition by Fitz, 1898). In earlier editions the chapters are numbered differently, but bear the same headings: "Why We Eat and Breathe," "Nutrition," and "Foods."

Many suggestions concerning the presentation of the general principles of physiology in connection with study of lower animals were gathered from *The Crayfish as an Introduction to the Study of Zoölogy*, by Huxley, and from Wilson's account of the earthworm in Sedgwick and Wilson's *General Biology*.

6. Summary of the Introduction

Attention is called to the study of the crayfish as illustrating the various standpoints from which any animal may be studied, namely, external structure with homologies and adaptations, internal structure and functions, gross and minute structure, classification based upon resemblances of structures, distribution in space and time, development of the individual, relation to environmental conditions, life histories and habits — these phases of zoölogy have been illustrated by study of the crayfish. Throughout the course it is continually impressed upon the pupils that no part of the study is exhaustive, and suggestions for work beyond this course are frequently made.

*Definitions of biology, zoölogy, botany, morphology, physiology, anatomy, histology, embryology, natural history.

II. Studies of Animal Types

The crayfish having served as a basis for the introduction to some of the most important aspects of animal structure, functions and relations, less extensive studies of representatives of the important groups of invertebrate animals follow, and to this work seven weeks are given. This in turn is followed by a study of common vertebrates during five weeks at the close of the half-year course.

In these studies of animal types the aim is to give acquaintance with common animals and to extend the application of the principles of morphology and physiology which are first introduced by study of the crayfish. Unless otherwise specified the laboratory study is from the standpoint of external structure, especial attention being given to those characteristics which underlie classification and adaptation to environment. It should be remarked here that, with the exception of a few instances, classification is not carried below the orders. Uses of parts are determined by experiment whenever possible, and stress is placed upon the study of habits, life histories, and ecological relations.

1. Crustaceans.

Examination of sow-bug (Oniscus), water-fleas (Daphnia and Cyclops) and barnacle (Lepas) (outline drawings).

*The crustacea, general characteristics, distribution in space and time, the principal orders, economic relations.

2. ARACHNIDS.

Examination of spider (outline drawings), and some observation of habits in the laboratory and in field. *Allies of the spider.

3. INSECTS.

a. "Grasshopper."

Examination of external structure (outline drawings). Study of habits. Stages in the life history (drawings and notes). Compare adults of two species.

b. Butterfly.

Examination of adult, caterpillar and chrysalis of the milkweed or monarch butterfly (Danais) (outline drawings, dorsal and lateral views). Observation on butterflies in the field.

c. Life histories of cricket, beetle, bee, ant, fly, may-fly, cicada.

Examination of adults and the larval stages (outline drawings and notes). Observations in the field. The larvæ of blow-fly, Cecropia and other moths, meal-beetle and other insects obtainable are kept under observation until metamorphosis occurs.

*Life histories of insects. Readings — Kingsley, *Comparative Zoölogy;* Needham, *Lessons in Elementary Zoölogy;* Weed, *Life Histories of American Insects;* Comstock, *Insect Life;* Davenport, *Introduction to Zoölogy.*

Collection of insects with at least two representatives of each common order; only familiar forms are identified as to genus and species.

*Protective resemblance, mimicry, parasitism, commensalism, social life and economic relations.

*Summary of the phylum Arthropoda — general characteristics as illustrated by the types studied, general classification. *The wealth of numbers of species and individuals, and the variety of form in the phylum.

4. WORMS.[1]

a. Earthworm.

External structure (drawings), movements and reactions of the living worm. Field observations. Examination of the general internal anatomy[2] (drawings and notes). *Life history of earthworm. *Economic importance.

*Structure of earthworm and crayfish compared.[3]

b. Flat worms.

Planarian (living) and tapeworm (drawings). *Life histories. *Parasitism.

c. Round worms.

Trichina and "horsehair-snake" (Gordius). *Life histories.

5. CŒLENTERATES.

a. Hydra.

General structure as illustrated by a living animal and longitudinal sections, budding, reproductive organs (drawings and notes). Movements, responses to stimuli, feeding. *Life history. *Radial symmetry. *Physiology of Hydra compared with that of the earthworm and the crayfish.

b. Hydroid colony (Pennaria, Obelia, Parypha or Campanularia).

Structure of a colony and of the individual zoöids (drawings). Compare zoöid with Hydra. Formation of medusæ. General structure of hydromedusa (Gonionemus) and of a scyphomedusa (Aurelia) (drawings).

*Life history and alternation of generations.

[1] For the purpose of this outline it seems best not to use the modern subdivision of this heterogeneous group.

[2] The earthworm is not easily dissected by a beginner, and preparations are used to illustrate the internal structure. The worms are dissected in the ordinary way, and pinned on strips of cork-linoleum. These strips occupy little space in the preservation jars, and can be easily removed and placed in pans of water during examination by the pupils.

[3] Attention is called to the possibility of more extensive study of the structure and functions of the earthworm, if time permitted.

c. Corals.

Sea-anemone (Metridium or Sagartia). External structure and transverse sections (drawings). Skeletons of Oculina and of Astrangia with zoöids in position. *Corals — life history, distribution, formation of the skeletons, island formation. Demonstration of skeletons of important corals.

6. Sponges.

Structure of Grantia (drawings). Fresh-water sponges (Spongilla). Commercial sponges. Glass sponges. *Life history, and formation of the skeletons.

7. Protozoa.

Paramœcium or Spirostomum studied in the laboratory. *Unicellular nature of Protozoa, protoplasm, nucleus, cell-activity, cilia, reproduction by division, intra-cellular digestion. (As far as possible these topics are studied by the laboratory method.) Various forms of Protozoa are demonstrated in order that the pupils may gain some idea of the variety of unicellular animal life.

*Physiological processes in unicellular animal compared with Hydra, earthworm and crayfish. *Physiological division of labor as illustrated by this series of animals.

*Review of the general characteristics of Protozoa, Cœlenterata, " worms " and Arthropoda in this order, which is the reverse of that followed in the original study.

8. Echinoderms.

a. Starfish.

External structure (drawings). Examination of animal with aboral part of skeleton removed, and demonstration of principal organs. *Functions of the organs. *Economic relations.

b. Sea-urchin (Arbacia), crinoid and sea-cucumber (Thyone).

These are examined for the characteristics which show their relationship to starfish, and are demonstrated in connection with lectures on characteristics of the phylum.

9. MOLLUSKS.

a. Gasteropods.

The Snails.[1]

Study of living animal, external structure (drawing from right side).

Observation of habits of living animal — movements, feeding, reaction to stimuli.

Examination of entire shell and longitudinal section. Compare size, color and markings of several shells: Structure — apex, aperture, umbilicus, lines of growth, columella, direction of twist (drawings). Structure of shell — three layers. Test with acid.

Animal removed from shell. Location of the organs which are visible without dissection (drawings as seen from right and left sides).

Examine shells of various marine gasteropods and compare.

Become acquainted with our native snails of genera Helix, Physa, Limnæa, Planorbis.

Examine set of Helix nemorosa showing individual color variation. *Individual variation.

Slug (Limax).

Examine living slug, and compare with snail. Observe movements and habits. Draw as seen from right side.

b. Lamellibranchs.

Mussels and clams.

Examine shell, right and left valves, inside and outside (drawings of right valve). Animal with right valve removed — location of superficial organs without dissection (drawing).

Living clams in aquaria. Currents indicated by powdered carmine (diagrams showing direction of currents). Locomotion. Feeding.

Oyster.

Examine several shells and compare forms. Locate structures mentioned for clam-shell. Compare right

[1] The European edible snail (Helix pomatia) is used because readily obtainable in New York markets.

and left valves (draw right valve, inside and outside views).

Demonstration of currents in living oyster. Microscopic examination of moving cilia on oyster gill. Cause of currents?

Examine oyster with right valve removed. Locate principal organs without dissection (drawing).

Examine young oysters ("spat").

Examine shells of other bivalves, comparing all points with shell of clam.

c. Cephalopods.

Squid.

External structure (drawing). Nautilus, examine alcoholic specimen and shell sectioned to show chambers.

10. VERTEBRATES. (*Five weeks.*)

a. The amphibians.

The frog.

Chief external characters (outline drawings from dorsal and lateral views).

Observation on the living frog. Movements, breathing, feeding, responses to stimuli.

Internal structure[1] — general structure of digestive, circulatory, respiratory, excretory, reproductive and nervous systems (diagrams of systems of organs).

Histology. Blood, muscle, epithelium of skin and intestine, liver, ciliated cells, cartilage and bone.

(Fresh material is used for most of this work and is supplemented by prepared slides.)

*Review of the cell-theory.

Development of the amphibian egg — laboratory study and lecture.[2]

*Oviparous and viviparous development — advantages and relative numbers of young individuals.

[1] Dissections in part by the pupils. Preparations by the instructor are kept at hand for reference and demonstration.

[2] This work comes at a season when developing eggs cannot be obtained, and material preserved in formalin is used. Later, when developing eggs are obtainable, outlines for observation at home are given to the pupils.

Examination of the external characteristics and habits of the urodele amphibians (salamander, newt, mud-puppy).

*The Amphibia — characteristics of the principal orders, and demonstration of the general characteristics having systematic value.

*General physiology. Principles of physiology first considered in connection with the crayfish are reviewed and with some expansion are applied to the frog considered as a type vertebrate.

The frog is used to illustrate the general biological features of the vertebrates. A general survey of the other vertebrate classes, designed to give general acquaintance with the important forms, follows the study of the frog.

b. The fishes.

Examination of a teleost and dog-fish for general external characteristics (outline drawings). Observation of living fishes — movements, habits, food, respiration, etc.

*Development, illustrated by a series of trout embryos. *Artificial propagation.

*The principal orders of fishes, and demonstration of their characteristics. *General characteristics of the class. *Economic value. *Geographical distribution.

c. The reptiles.

Important orders and their characteristics, as illustrated by demonstrations of lizard, snake, alligator and turtle.

*General characteristics of the class. *Geographical distribution. *Useful members of the class.

*General aspects of the embryonic development — demonstrations of embryos.

d. The birds.

*Important orders and their chief characteristics. Useful birds. *Suggestions for field study.

Demonstrations — series of chick embryos. *General sketch of the development.

e. The mammals.

Principal orders[1] — their characteristics and familiar representatives.

*Examination of skeletons of frog, turtle, bird, cat, monkey and man. Special attention is directed to the homologies of the limbs (outline drawings).

*Homologies among vertebrates. *Analogies. (Illustrated by preparations and lantern slides).

*Review of the distinguishing features of the five classes of vertebrates. *Evidences of relationships (demonstration).

*Characteristics of the phylum Chordata. *Primitive Chordates.

*Fossil vertebrates and their relation to living types (demonstrations at museums).

*Review of the general classification of animals. Practical tests of pupils' ability to recognize representatives of important groups.

*The evidences of common descent of animals — evolution.

Application of the general principles of morphology and physiology, which the course has introduced, to the structures and activities of the human body.

*The zoölogical position of man in the light of structure.

NOTE. — The pupils in this year's class have had the usual "elementary physiology," and gave evidence of readily grasping the above comparisons. In previous practice, when more time was assigned, it has been found profitable to lead into consideration of the functions of the human body from a more advanced view-point than is possible in the usual elementary course. This study of the human body and its functions from the comparative view-point is, in the opinion of the writer, the most important application of the general principles of zoölogy.

Extension of the Course from Half-year to Full-year

It is evident that in a half-year's course many of the topics mentioned in the outline must be given rather hasty consideration.

[1] It is proposed to make next year's work on birds and mammals more practical by examining representatives of the orders at the American Museum of Natural History and at the Zoölogical Gardens.

In case it becomes advisable to extend the course throughout the year, giving double the time, no great modification of the outline need be made. In addition to more stress upon the study of the human body, as suggested in the above paragraph, many of the topics may with profit receive more time, each type of animal may be studied less hastily, and more allied forms may be examined for the sake of a wider acquaintance with animals and animal life.

Appendix A

The Crayfish as an Introductory Type

The crayfish has been chosen after consideration of mammal, frog, fish, crayfish, grasshopper and earthworm. After starting various groups of pupils with four of these forms, the writer has come to believe that the crayfish has some decided advantages as a form with which to begin the practical study of animals.

First, pupils have less aversion to handling the crayfish than in the case of any of the other forms, except the insect. Teachers will recognize that this is an important point, for the first impression largely influences the pupil's attitude toward a subject. An objection to the insects is that they are highly specialized and do not so well illustrate general principles, and the small size makes it impossible for beginners to study the internal anatomy. On the other hand the crayfish is easier to dissect than any of the other forms, and the general structure is easily understood by even very young pupils. The internal organs are comparatively simple, and yet there is such physiological division of labor that definite organs have particular functions. The complexity is not so great as in the case of a vertebrate, and it is easier for the pupil to gain a clear idea of functions of organs as related to the life of the body as a whole.

The external structure is very favorable for teaching principles of homology and classification at the same time that habits of scientific observing are being developed. So far as observation of a living animal is concerned, it is hardly possible to begin with a more favorable form.

Finally, there is a great advantage in that the animal can be readily obtained in most places outside of New England, and is found in the markets of the cities.

Appendix B

Methods of Conducting the Course

The course is introduced by laboratory study which is made the basis for supplementary reading, lectures and recitations. This plan is followed throughout the entire course, and no animal is extensively considered until the pupils have had some personal acquaintance with the form; and no structure is described which is not illustrated by the pupils' laboratory studies or by demonstrations given by the instructor. It is believed that there are enough important things which the pupils can see for themselves, and as a rule it is quite unnecessary and undesirable to discuss animals or parts of animals with which the pupils do not have a personal acquaintance.

A brief statement will make clear the minor methods of conducting the work. The various points included in the outline for laboratory work are presented to the pupils in the form of mimeographed directions which set problems for the pupils to solve. A special attempt is made to guard against the common error of giving problems which are quite impossible for a beginner — such are better demonstrated by the teacher or omitted altogether. There are enough important problems which the pupils with some direction can solve with certainty. Experience has shown that the direction for working out a problem can in the beginning scarcely be too complete. Brief outlines for laboratory study are worse than meaningless to the young beginner. In order to get the best training every step of the way should be clearly pointed out. If classes are small it is better for the teacher to give much of the direction verbally, but with large classes the printed directions may give the pupils much valuable help, which the teacher cannot possibly find time for giving.

Especially with regard to problems too difficult for a beginner is it necessary to be careful in the study of living animals. The results to be obtained from many experiments suggested by authors are of very doubtful value, since science yet awaits an interpretation.

With regard to the supplementary work in lecture and recitation it has so far been necessary to dictate notes on subjects which require explanation and supplementation, but these notes are being expanded into text-book form and in mimeographed

sheets will hereafter be put into the hands of the pupils. For supplementary information in the line of natural history references have been given to certain chapters in elementary books.[1]

The laboratory records are kept by means of both outline drawings and notes. The pupils are required to express in writing some results which cannot be illustrated by labelled drawings. The common tendency to create in the mind of pupils the impression that the making of a note-book is the chief end of laboratory work is believed to be the result of undue emphasis which many teachers place upon notes. It is held that there are many results of observation which are better recorded in the memory, and practice along this line is frequently given, the pupils being tested by verbal questioning. A teacher can judge pupils by their attitude when at work far better than by note-books alone. Note-books should be kept for the sake of the training, which the preparation gives, and as a record for persons who have not seen the actual working of the pupil.

The Course in Botany

By FRANCIS E. LLOYD

A. INTRODUCTION

There are, at the present time, two main schools among teachers of botany, representing a difference of opinion chiefly as regards the way of approaching the study with a class of elementary students. This difference has already been alluded to in the closing paragraph of the preface. To restate it briefly, the one school attacks the study at the lower end of the scale of life, advancing from the simple to the complex. The other begins at some convenient point which involves the minimum amount of technical difficulties and of strangeness, and is content to sacrifice the appearance of logic for a way which offers less friction. Setting aside this divergence, there appears to be a fairly

[1] After this outline was completed, the writer had an opportunity of reading the new *Introduction to Zoölogy*, by Davenport. It was noticed that in general the book well covers the ground with respect to the natural history studies which during the past year were included in the Horace Mann School course in elementary zoölogy, and it will be useful as supplementary reading in connection with very many topics.

general understanding as to the amount and kind of matter to be presented. Courses differ, to be sure, in details, but these may be accounted for by local conditions, as for example the experience and abilities of instructors, the time allowed and the maturity of the students. This general agreement lies in the demand that the student have opportunity to acquaint himself with the essentials of plant structure, physiology and ecology. Furthermore, it asks that this knowledge shall not be confined to one group of plants, such as the Spermatophyta, but that the student should gain a knowledge of the more readily observable facts about the lower forms as well. It is also generally insisted on that a physiological view-point should be had.

Between such courses as carry out more or less fully these ideas and the one now before the reader, there is a certain amount of parallelism. But in the method of attack this outline in particular agrees more especially with such courses as are to be found outlined in Spalding's *Introduction to Botany* and Bergen's *Botany*. The writer desires to acknowledge the former especially as a source to which he is indebted for valuable suggestion for a number of years, and especially at the beginning of his teaching experience.

It is, however, believed that in the course as here worked out there are several points of difference which may be mentioned. One of these lies in the emphasis placed upon the study, first of all, of the fruit rather than the seed. The method of beginning with the seed the writer followed for a number of years, until it was found deficient in the treatment of difficulties growing out of a study of the 'grain' of Indian corn, a study which we rightly persist in, but which has taxed and still taxes the understanding of very many students and not a small number of teachers of botany. The difficulties referred to are those arising out of the persistent indehiscent pericarp which closely invests the seed. The latter, during its growth, loses its integuments by absorption, and it has been shown that the inner layer of the pericarp suffers the same fate.

In addition, the morphological questions involved in a study of the grass embryo have been the subject of wide discussion, and indeed can hardly be said to have been answered as yet. By virtue of this wide departure from the usual, the Indian corn has been a classical object of research, while in spite of these it

has, on account of its size, been made the basis for instruction. In addition to its intrinsic value as material for teaching, on the grounds above stated, it is of more than usual value to American teachers and students because of its economic importance.

By instituting then a comparison of the obvious morphological features of the fruit of several forms, and by the selection of proper materials on which to base this comparison, it has been found possible to obviate the difficulties mentioned, and to lead the student to a correct understanding of the fruits studied. More specifically, the task set for the student is to identify the parts of the leguminous fruit, drawing attention to the internal relations. By the use of corn taken before and during anthesis, and of ripe sweet corn, the homologous parts are readily identified, and the student is thus forced to the conclusion, otherwise difficult to form, that we are dealing here with a fruit, the pedicel of which is short and thick, and the locule of which is completely filled by the seed. This conviction is strengthened by the examination of a grain of 'rice' pop-corn, in which the pericarp is somewhat inflated, or at any rate not completely filled, at the base of the style, by the seed.

It has also been found to be of no little value to ask the student to compare the old and young condition of the fruit in each case, with the object of leading him to the idea of development rather than to a statical conception of the matter in hand. The importance of this can hardly be over-emphasized, for the tendency of botanical teaching in the past, now happily growing less marked, has been to view plants from the latter point of view, one which can do little else than to lead to a one-sided and so distorted idea of plant life. The reaction against this method has been seen in the publication of several text-books, unquestionably of merit in themselves, but which seem to represent once again a too radical change in the theory of teaching, though possibly less actual change in practice.

It will be found on perusing this outline that the amount of detail given varies materially in different parts. This is done for the reason that it has been deemed unnecessary to state more than briefly those subjects which may be found sufficiently treated in the numerous text-books and laboratory guides in prevalent use. Those parts, however, which are to be met with less

frequently or not at all, have received a more detailed treatment according as the case has demanded.

Attention may be called more particularly to the method of treatment of foods in plants, and of digestion and absorption, a method which has been adopted from those of the physiological chemist and which has been found admirable in practice for its applicability to elementary teaching in spite of technical difficulties always confronting one who is making an exact study in this difficult field of inquiry. This method has an additional advantage in rendering entirely unnecessary any microscopical examination of food,[1] involving as it does micro-chemical reactions, which, however valuable they may be for the advanced student, are certainly too difficult for the beginner, especially in the high school. In particular it has been the object of the writer to bring clearly before the student the problem of digestion, a subject which has given no end of trouble and which is often veiled in misconception. The essential similarity of plants and animals in this regard is in this way brought into prominence. In this connection the writer desires to bring to the attention of teachers the great value of the cocoanut and of the date as material for demonstrating the morphological facts involved. The necessity of absorption is brought out by these much more strikingly than in the case of smaller forms. To be sure, there is the difficulty of obtaining material, not in the first instance, but of developing seedlings. In the date, however, this is extremely easy (see footnote on p. 44), but in the cocoanut less so. Let it be said, however, that any trouble and patience necessary in getting good specimens is more than justified by the results which accrue. The exceedingly beautiful, large haustorium (the cotyledon) and its relation to the endosperm, can be demonstrated to a large audience with the effect above noted of bringing clearly to the mind the conditions which make digestion necessary.

That part of the outline dealing with types of plants will not be found to carry one far off the beaten track. It will be observed, however, that the ecological point of view is maintained throughout, for it is contended that the small amount of work which the curriculum permits is not sufficient to lead the student

[1] The examination of starch, and its color reaction to iodine, is observed microscopically on account of its ease.

to any but a very imperfect conception of the relationships of plants. A course, however, which failed to bring out clearly the fact that such relationships exist would strike very wide of the mark. The writer has had occasion to examine a considerable number of students who have been subjected to courses which purport to attain this end, and he has failed to find one such student who was able to show signs of knowledge of this kind. It is the point of view which is here aimed at; it is not the ability to give the term descriptive of the shape of a leaf, but rather to ask an intelligent question about the part which that leaf may play in the economy of the plant, and how that end is the better attained as a result of the form and structure of that leaf. To repeat, it is the dynamic and not the static conception that has been given prominence.

It is becoming the custom to add to the ordinary elementary course, as outlined in certain recent text-books, a section dealing with the ecology of plants. One might almost assume that here was a new and sudden development in the teaching of botany. It is, however, the outcome of a commendable movement which may be traced back a number of years. The plan, however, of making the topic something almost apart from the general subject is to be deprecated. Thus, even in appearance, to divorce ecology from the rest of the science is not in accord with the modern conception of a 'synthetic' rather than of an 'analytic' method of treatment. Morphology has no meaning apart from physiology, and a synthetic treatment of these leads to ecology.

Again, much less strain has been laid upon a study of sexual reproduction in the narrower sense than upon a study of the vegetative body and the more readily observable phenomena of adaptation. Some knowledge of the evolution of the shoot and root as exemplified in the gametophyte and in the sporophyte is considered of more value than a more exact knowledge of homologies, a subject which taxes the understanding even of mature students.

It must not be supposed, however, that the matter of sexual reproduction is neglected. It will be readily understood that a subject which is so special and difficult can hardly be regarded as fit for high-school students. And yet it is a subject, the essentials of which may be very clearly brought out in a study of such forms as Spirogyra and Vaucheria. The attempt is

seriously made to show that the fact of sexual reproduction exists also for other forms, without entering far into morphological details. In taking up the seed plants in this connection, somewhat more attention is paid to details, and the important morphological facts involved are demonstrated by means of charts and preparations. At this time also is demonstrated the phanerogamic embryo in earlier and later stages of development, and so the study of the life cycle, which was commenced by the study of the fruit, is rounded out to completion.

There is a further point of importance in that the very natural and essential facts about the subject of sexual reproduction may be made a part of the knowledge of young students. Such knowledge, it is believed, helps to lift the mind to a normal conception of a question which is in the young mind very frequently befogged and distorted to the pronounced detriment of the moral nature.

It may also be worth while to point out a few practical considerations which make the carrying out of this course feasible. Some exception may be taken to the amount of time and work necessary to cover the ground indicated, for when the amount of time actually given to this study is summed up, it is after all but little. The objection, if such is raised, will be removed when it is understood that a detailed study of everything is not required, nor is it expected that everything that is studied, or in any way examined, shall be drawn. With reference to the first point, it must be further explained that an effort is made to give the student an opportunity to see a good many forms, so as to enrich the field of observation. To this end, when the opportunity offers, excursions are taken to glass houses, museums and the field. Here again it must be said that only a few such excursions may be planned, and these are of necessity brief, on account of unfavorable local conditions. As to the drawings in the laboratory note-book, when such are demanded, only the simplest outlines are required. Any attempt at more elaboration is usually suppressed, as the amount of time at the disposal of the class is too limited to allow it.

Quite a number of matters are to be found also in the outline which are not done by the student, but which are, however, in some way or other brought to the pupil's notice. This is done by means of demonstrations. The practice of devoting a whole period to the study of preparations and diagrams of special in-

terest has been found profitable for young as well as for more mature students.

In carrying on the work in the laboratory, the student is given detailed outlines prepared for his guidance during each exercise. These are planned to lead him to make careful observations. It has, however, been the aim to make it necessary for the student to do some real thinking for himself, and to this end the detailed outlines are put partly in the form of questions. It is very easy to swamp a beginner with questions, and this should be avoided. At the same time the obsolescent method of verification is deemed insufficient for educational purposes.

In addition to the outlines for the laboratory work of each day, a number of questions are formulated from time to time covering given parts of the work. These questions have been found useful in helping the student to focus the attention on the more essential points, and are in a sense a measure of his success in the study. Additional tests are given in the form of brief essays on very definite topics, such as a particular experiment. A fair amount of thoroughness in such work is taken as a basis for standing, in lieu of the examination.

The use of a text-book is required for the reason that the contents of the note-book are, even under the best of circumstances, too incomplete to warrant entire dependence upon it. The text-book is for reference and must be used in connection with and after the work which is done in the laboratory.

Reading in addition to that in the text-book is occasionally required. The plan of assigning a piece of reading to a particular student who is expected to give for the benefit of the class a clear and concise account of his study of the reference has been found to bear good results. For this purpose some of the shorter publications of the government and of state agricultural experiment stations have been found good. In such ways as this the students are brought to appreciate the work of the government and the value of it economically considered.

Other sources for reference are found in text-books of various authors, and in other writings of a less special kind, such as Geddes' *Chapters in Modern Botany;* Kerner-Oliver's *Natural History of Plants,* and the like.

B. OUTLINE OF THE COURSE

I. The Structure and Physiology of Plants

1. THE LIMA BEAN: The fruit and seed.

a. The fruit:

External features of the pistil and of mature fruit compared: pedicel, ovary, style; the relative rapidity of development of these parts.

Lateral view, one valve removed, with seeds in position: the funicle, strophiole[1] and micropyle.

Transverse section of the fruit taken through the funicle of one of the seeds: valves of the legume, oblique striation of valves, and the sutures, the seed coat, cotyledon, and the lateral insertion of the funicle on the pod. Dissemination.

b. The seed:

Fresh and dried seeds compared:

External characters: hilum, chalaza, micropyle and strophiole.[1]

The embryo: hypocotyl,[2] plumule, cotyledons, the vascular tissue and root cap as seen in longitudinal section.

2. THE INDIAN CORN.[3]

a. The fruit:

The 'grain' and a pistil[4] taken during anthesis compared each with the other and with the bean fruit: pedicel, ovary and style; the base of the withered

[1] This structure is not considered important as far as the student is concerned, but as it is often noticed and inquired about, it is deemed worth while merely to mention it.

[2] Not a little confusion exists in the terminology of the stem of the embryo. The term hypocotyl is here used as applying to the *whole* of the axis below the cotyledons. The radicle is therefore the lower end of the hypocotyl. The root is thus regarded as originating in the stem.

[3] This type is taken next because the transition is simpler than to the castor oil.

[4] The material is collected during anthesis the previous season and preserved in 5% formalin. Each student may then see an ear of corn at this interesting period of its growth. Ripe ears are also used. A chart showing a diagram of a longitudinal section of the perfect pistil is shown.

style in the mature grain of sweet corn and rice pop-corn.[1]

b. The external features of the embryo in longitudinal and in transverse section; the endosperm.

3. The Castor Oil Plant.

a. The fruit:

External features in young and old specimens compared. Comparison also with the fruit of the bean. The striations on the endocarp showing after the exfoliation of the exocarp. Compare with striations of the bean pod. Dissemination in both compared.

b. The seed:

External features in young and old specimens: hilum, raphe, chalaza, caruncle, micropyle.[2]

Internal features; the endosperm; the embryo and its parts.[3] Relative position of radicle and micropyle.

4. The Pine.

External features of the young ovule-bearing scale and the subtending scale or bract.[4] The ovules and the young wings.

Old scale with mature seeds and wings. The manner of attachment of the wing to the seed.

Structure of a seed[5]: integument, micropyle, endo-

[1] Rice pop-corn is useful for comparison on account of the empty space at the base of the style.

[2] The difficulty experienced in finding the micropyle makes it profitable to have a chart showing a longitudinal section of the seed. A similar section of a young seed (ovule) is also shown for purposes of comparison, and as an illustration of the value of developmental study. The same chart shows also the chalazal pore and entrance of vascular tissue, the significance of which is seen more fully later on. Longitudinal sections are demonstrated. It is to be noticed that the testa in this seed is a part of the *inner* integument. This is incorrectly stated in some texts.

[3] Seeds should be well soaked (48 hours) to insure successful dissection, otherwise the cotyledons will break and stick to the endosperm.

[4] Suitable material is collected, preferably in the spring, from firs or spruces. Young pine cones are not so good, but serve the purpose.

[5] The seeds of a western pine (*Pinus Coulteri* or *P. sabiniana*) are very good. They must be soaked well (for a week or more), and can then be split open longitudinally without damaging the endosperm or embryo. Such materials must be obtained from seedsmen.

sperm, embryo: cotyledons, hypocotyl, radicle and root-cap.

At the close of the foregoing study a short time is spent in examining a small collection of fruits and seeds, illustrating a number of different methods of dissemination. Especial attention is drawn to

(1) The correlation between the number of seeds produced in a locule and the method of dissemination, and

(2) The analogies existing between the seed coats of some seeds and the pericarp of indehiscent fruits.

5. STUDIES IN GERMINATION.[1] — The four types mentioned above, together with others, are used for the study of germination.

a. Absorption of water; localization of

b. The rupture of the seed coats (and pericarp in certain forms).

The exact manner of rupture.

The cause of rupture.

Special adaptations:

The 'peg' or 'heel' (e.g. squash).

The stem-pad (e.g. corn).

The lid and radicle of certain monocotyledons (e.g. Tradescantia, date).

Growth of endosperm (e.g. Ricinus).[2]

c. The precise manner in which seedlings break through the ground: behavior of the epicotyl (pea), hypocotyl (castor oil) and cotyledon (onion).

d. The development of the organs found in the embryo:

Direction of growth.

Amount and relative rapidity of growth of various organs. Determination by experiment of the zone of growth in the root. Movement of the zone of root hairs.

Irritability of root and shoot: geotropism, phototropism, hydrotropism, traumatropism, thigmotropism.

[1] It is well to soak seeds thoroughly in order to secure prompt germination.

[2] The castor oil seed germinates well — albeit a little slowly — and is a very beautiful type for these observations. Seed may be purchased at small cost from seedsmen. The variety "Zanzibarensis" has the largest seeds, which are therefore the best for laboratory work.

e. The behavior of the cotyledons during germination:
As food-storage organs mainly or wholly.
As storage organs partly, and later as foliage leaves (e.g. squash, onion).
As food-absorbing organs (e.g. corn, cocoanut, date).

f. Form of the earlier leaves compared with the adult form.

g. The production of other shoots (in the pea) after the destruction of the plumule.

h. Etiolation. The behaviour of growing seedlings in darkness. Seedlings which are grown in darkness,[1] and planted deeply in the soil, are compared as to *form* and *color*. The ecological significance of their behavior.[2]

6. RESPIRATION.

It is found advantageous during the study of germination to demonstrate the necessity of oxygen for growth. This is done by attempting to grow seeds[3]

[1] Small (2-3 inch) pots, which cost but little, are very useful for such work. A completely dark chamber can be made of metal (tin or galvanized iron) in the form of a can without the lid. Large coffee cans can be used for the purpose. Cover the pot with the can, the whole standing on a bed of sand.

Not only seeds but other plant structures (tubers, bulbs, corms, e.g. Indian turnip) might be experimented upon by the teacher, and the results reported to the class. It cannot be too much appreciated that a teacher's power and influence is increased very greatly if he is doing more work of this kind than a class can do, for lack of time or other reasons.

After the specimens are grown, especially if striking results are attained, a set of three seedlings, one a control, showing the different behavior, may be fastened on a slip of glass with gelatine, labelled and preserved in 5% formaline. The sheets of glass can be cut so as to be placed in cheap preserving jars, or specimens may be sealed up in glass tubing. For valuable suggestions see Stone, G. E., "Formaline as a Preservative for Botanical Specimens," *Journal of Applied Microscopy*, Vol. 2, No. 10, p. 537.

[2] The lengthening of stems must be regarded as an adaptive feature, and not as an abnormal or pathological condition. The following literature in the study of etiolation may be mentioned as valuable for reference. MacDougal, D. T., "Light and Vegetation," *Popular Science Monthly*, 54: 193-201, December, 1898.

[3] Oats, in which there is but little intramolecular respiration, are used. The experiment as recommended by Ganong (*Botanical Gazette*, Vol. 27, p. 255, 1899) has been found very satisfactory.

in an atmosphere devoid of that gas. A control experiment must of course be set up.

Respiration involves chemical change. The latter results in the evolution of heat. That chemical changes are taking place in germinating seeds may be shown by means of two accurately paired thermometers (one for a control experiment), as indicated by Detmer.[1] Seeds killed with formaline are used in the control.

7. NUTRITION (FOODS). — The kinds of foods, and methods of determining their occurrence, especially in seeds.

Some phases of the physiology of nutrition are studied in connection with the work outlined in the preceding pages. The subject is taken up here in the following manner.

a. Proteids.

Demonstration of the reactions of an acknowledged proteid by applying the following tests to a weak solution of egg albumin in water:

Coagulation by heat. Test the coagulum with nitric acid and ammonia. Boil a little of the albumin in nitric acid, *cool* and add *slowly* ammonia.

Determine whether proteids occur in the seeds which have been studied, or other seeds.

Grind up as finely as possible in a coffee mill about 25 grams of dry seeds. Make extracts as follows:

(1) With water (100 cc.), allowing to stand for 24 hours. Test the extract obtained with the above tests, and compare the results with those obtained above with egg-albumin. Note the similarity of animal and plant albumin.

(2) Taking the same material, extract it with a 10% solution of common salt. A second proteid, insoluble in pure water, will thus be obtained. Obtain this in dry form by dialysing and drying. This may then be examined and tested as above.

(3) A third proteid may be obtained from wheat

[1] Translation by Moore, p. 28.

by taking the flour, making a dough, and then washing[1] the dough in a cloth under the tap. The sticky substance, gluten, is a proteid which is insoluble in water, and should be tested with nitric acid and ammonia.

(4) Does gluten occur in peas? The question should be answered by applying the method in (3).

The above work is done by the instructor for the class. The students repeat the nitric acid-ammonia test on the solid food-storage parts of the seeds they have studied. After boiling the substance a moment in nitric acid in a test tube, pour off the acid and add a drop or two of ammonia. Millon's reagent for proteids may be substituted, but it must be fresh and obtained from the makers. The food-storage parts must be heated in a little of the reagent.

b. Starch.

Demonstrate the color reaction of starch with iodine by adding the latter (a very weak solution) to some *very thin* starch paste.

Examination of starch grains in the cells of the potato tuber,[2] mounting the section in very weak iodine solution,[3] drawing of one or two cells with contained starch grains.

Application by the students of the iodine test to determine the presence or absence of starch in the seeds studied.

c. Sugar.

Determine the color reaction of Fehling's solution and grape-sugar or glucose[4] by boiling them together and obtaining a red precipitate.

[1] By saving the washings, chiefly composed of starch, a rough estimate of the relative amounts of starch and proteid may be obtained. The water-soluble proteids are of course partly or wholly lost, according to the thoroughness of the operation. Recall the value of wheat as a staple.

[2] If a rather thick section of the tuber is first well rinsed in water, the starch will be washed out of the broken cells so that the cells left intact are more or less isolated.

[3] Made by adding crystals of iodine to a weak solution of potassium iodide in water.

[4] Ordinary sugar of commerce may be used, but must be remembered to contain cane sugar for the most part, which does not react to the Fehling's solution. The test thus made is therefore not very satisfactory,

Tests are applied to the seeds studied by the student for the determination of the presence of sugar.[1]

d. Cellulose (reserve cellulose). It is pointed out that this food substance does not occur in any of the seeds heretofore studied.

Demonstration of the hard white reserve cellulose as it occurs in the date or persimmon seed.

Using a well soaked seed, make a thin section with a sharp knife, place the section on a piece of glass in chlor-zinc-iodine.[2]

e. Oils.

Demonstrate the solubility of an oil (e.g. cottonseed or olive oil) in ether.[3]

Grind up some of each kind of the seeds studied, and extract them with ether. Place the extracts in glass vessels, and examine after the ether has passed off.

f. Mineral substances.

Burn off the other substances present in the seeds studied. The mineral substances present will thus be demonstrated. It should be pointed out that a large percentage of the materials so isolated is probably of use to the germinating seedlings. A subsequent experiment will demonstrate the importance of mineral nutrients.

After the above work has been concluded the results are brought together in tabulated form. The interchangeability of certain foods is also discussed.

8. The Digestion and Absorption of Foods.

From previous considerations, food is seen to be a source of energy. This is demonstrated by planting

as only small amounts of other sugars occur. The cane sugar may, however, be inverted by adding a little dilute sulphuric acid, and allowing it to stand. A reducing sugar will be formed.

[1] When negative results are obtained it is well to test other parts of plants (grapes, buds, etc.) in order to obtain positive ones. The value of a negative result must, however, not be overlooked.

[2] This reagent would better be obtained of dealers, as it is difficult to make good.

[3] Naphtha or benzine may be used, but do not pass off as readily.

peas and corn embryos from which the store of food has been removed.

Examination of a series of seedlings of the date.[1]

Study of the structure of the seedling which has been freed from the endosperm, noting especially the enlarged end of the cotyledon which serves as a sucking organ or haustorium; note also the absence of any visible openings through which food particles might pass. Recall the conditions in the corn and compare. The analogy between this condition in the date seedling and the apparatus used in an osmose experiment. Demonstration of diffusibility of some substances, and non-diffusibility of others.

Note the insolubility of cellulose, and also

The zone of disorganized cellulose about the haustorium.[2]

It is evident, in order that food may pass from the endosperm to the embryo, it must be in the condition of solution.

Make some very thin starch paste, boiling well. A very little of this starch is in solution. Test for sugar: Place in a dialysing bag and attempt to dialyse. Testing the water outside the bag for starch and sugar yields negative results.

From this experiment it is further evident that foods must be something more than soluble in order that they may be available for the growing seedling; i.e. they must be *diffusible* as well as soluble. In view of the insolubility or indiffusibility (or both) of most foods, e.g. proteids, starch, cellulose, cane sugar, it remains to be shown that these substances (or rather, one of them to serve as an example) may be rendered both soluble and diffusible.

Take some thin starch paste, add some saliva, place in a dialysing bag[3] and dialyse. Test the starch paste

[1] After two weeks' soaking date seeds will germinate in moist sawdust in six weeks or two months; a shorter time would probably suffice under favorable conditions.

[2] This can best be done by means of a specimen cut transversely and by means of diagrams bringing out clearly the condition found.

[3] Such a bag may be made of sausage skin, well cleansed and freed from oil.

and the fluid outside of the bag for sugar. Compare with experiment above. The positive results show clearly that starch may be rendered soluble and diffusible, i.e. may be digested.

Repeat the experiment, but using diastase[1] instead of saliva. Comparison of the essential facts of the process in animals and plants.

Review of the study of the cell with especial reference to the cell wall and the condition which foods must be in in order that they may be translocated from one part of a plant to the other.

9. The Structure and Functions of Roots.

a. Examination of a root system of the ordinary type.

Tap root.

Structure of the transverse section: epidermis, broad cortex, stele.

Root hairs.[2]

(1) origin and shape;

(2) cytoplasm and nucleus; the phenomenon of plasmolysis, and the staining reaction of dead and living protoplasm;

(3) the attachment of soil particles to root hairs.

The root cap: its structure and use. The secretion of acid by roots.

Secondary roots: their endogenous origin, their arrangement in orthostichies correlated with arrangement of tissues in the tap root.

Adventitious roots, their deep origin, well shown by means of sections taken transversely through the first node of young corn seedlings.

b. Absorption of water and of mineral substances in solution by roots.

Wilting after removal of soil from the roots.

Wilting after watering with a solution of potassium nitrate (referred to plasmolysis of root hairs).

[1] May be obtained at trifling cost from dealers in chemicals.

[2] May be obtained in great abundance and in the best condition for study by placing sprigs of Tradescantia in water. Numerous adventitious roots will then start from the nodes.

Demonstration of loss of water by a plant:
By collecting the vapor transpired, by condensation;
By measuring the loss of weight in a water culture or potted plant.
Osmose. Work done in raising a column of water.
Root pressure experiment.
The path of water (and dissolved salts) in the root: (1) through the cortex; (2) through the vessels.
Recall the work in connection with digestion (p. 43).

c. The mechanical fixation of the plant by means of roots.
In the soil: ordinary fibrous roots; "guy-roots," e.g. corn.
In climbing plants as organs of attachment, e.g. English ivy, poison ivy.

d. The modification of roots correlated with the storage of foods.
Primary roots, e.g. turnip, carrot, etc.
Other roots, e.g. sweet potato.
Tests for various foods found in such structures.
Vegetative reproduction by means of roots.

e. Modification of roots correlated with the parasitic habit.
Haustoral roots[1] of Cuscuta, by means of living cultures and preparations.

f. Mycorhizal roots; root tubercles.
Nature of the association: symbiosis.
Economic importance: e.g. the cowpea in the southern United States.

g. Air roots.
Conditions in the tropical regions.
General structure of air roots, especially the velamen.

h. Modifications of roots correlated with respiration.
Cypress "knees."
Respiratory roots of many swamp plants; e.g. Avicennia.

i. Contractile roots. Their ecology.

[1] The doubtful morphological value of the haustoria of Cuscuta may be mentioned. But the subject is too difficult a one for beginners.

10. THE STRUCTURE AND FUNCTIONS OF THE SHOOT.

a. The stem.[1]

External features of the stem.

Node, internode.

Positions of leaves as indicated by leaf-scars. The scars of the bud-scales and the limits of annual growths in twigs as indicated by these.

The method of branching as indicated by the relative positions of buds and leaf-scars. Recall experiment in which axillary buds are induced to grow after excision of the plumule (see p. 40).

The inflorescence as a system of branches.

(1) The flower regarded as a shoot.

(2) The raceme and its modifications: spike, head.

(3) The panicle.

The habits of trees, so far as determined by the relative rapidity of growth of different shoots. Compare with inflorescence.

Lenticels.

The growth of lenticels.[2]

Communication of interior tissues with the outside through the lenticels demonstrated by displacement of air.[3]

Internal structure of the stem.

Medulla, central cylinder, cortex and epidermis.

Phloem, xylem, cambium, medullary rays.

Secondary changes.

Exfoliation of the epidermis; formation of bark. Secondary phloem and xylem. Annual rings. Cor-

[1] For the general characters of the stem, bean, horse-chestnut, ash, or maple, willow, poplar, and beech are used very profitably.

[2] The development of the lenticels may be very beautifully exemplified by placing short twigs (I have used those of Catalpa with marked results) in a bottle with a little water in the bottom and loosely stoppered, so as to keep the air moist. The lenticels will then develop, especially those which are submerged (in Catalpa), showing the method of splitting, the loose tissue and the green color of the inner cells, previously to the development of the bud.

[3] As in the experiment in Detmer-Moore, p. 172. An aspirator is used.

relation of external features of the twigs as above noted with the internal structure.[1]

Method of determining the age of a tree. Possible sources of error.

The apical region of the stem; the exogenous origin of branches. Demonstration of sections illustrating these points.

b. Functions of the stem.

(1) As a mechanical support of leaves and other parts.

Rigidity of the stem produced by turgor, setting up tissue tensions.

Review of observations on osmose.

Experimental observation of herbaceous stem.[2]

Measurement of a piece of stem (or petiole); measurement of the central and peripheral parts after their separation by longitudinal splitting.

Effect of plasmolysis of the same parts; measurement before and after plasmolysis compared.

The artificial cell.[3]

Microscopical observation of a transverse section of such a stem, showing the absence of thickened cell walls in the central portion and the cells with thickened angles (elastic tissue) in the peripheral region.

Rigidity of the stem produced by the development of mechanical tissues (thickened cell walls).[4]

Comparison of rigidity of a woody stem with an herbaceous stem by tests of resistance to lateral traction, both before and after removing the outer zone of tissue. Comparison of herbaceous and woody stems living and dead.

[1] Students should be asked to verify their own conclusions derived from a study of external marks, by counting the rings of growth after making transverse cuts with a keen knife.

[2] A calla-lily peduncle, rhubarb petiole or arisæma peduncle is good.

[3] Can be made by filling a piece of sausage skin with strong molasses, tying up both ends, and placing it in water.

[4] Among others, the stem of smilax is very valuable, especially for the microscopical examination of thickened cell walls.

Distribution of mechanical tissues in the stem. Relative effectiveness of various arrangements. The condition in climbing plants.

Comparison of solid and hollow stems, e.g. grasses.

(2) Transportation of water and food materials.

From the soil to the upper parts of the plant. The path of water in the stem and leaves determined experimentally. Rapidity of ascent.

From the leaves to the lower parts.

From water culture experiments it has been determined that no organic materials are absorbed from the soil by the roots.

Determination of the presence of starch in subterranean parts.

(Evidence from experimentation upon leaves will complete the chain of evidence.)

(3) Stems as climbing organs (e.g. Ampelopsis).

(4) The storage of foods.

(*a*) Stems which are of less importance as mechanical agents, but which contain a larger amount of reserve food, and which usually grow along, or below, the surface of the ground. (See also under "Buds.")

(*b*) Stems showing a large amount of modification due to special activity in food storage, e.g. potato, crocus, corn.

(5) Water storage, e.g. Cacti, certain Euphorbias, and Salicornia (containing large special water cells).

(6) Vegetative reproduction, e.g. crack willows; separation of branches by decay, runners.

(7) Production of stem from roots. The condition of a neglected orchard.

c. The leaf.

A typical foliage-leaf.

External features: form, venation, comparison of leaves of monocotyledons and dicotyledons, variation. Mechanical function of venation determined experimentally.

Ecological relation of form and leaf position; relation

also to the position of the branch. Correlated leaf movements.

Internal structure.

Epidermal tissue, the structure and distribution of stomata.

Mesophyl: palisade and spongy tissue; intercellular spaces.

Vascular tissue.

d. The functions of a typical foliage leaf.

Transpiration.

Determination of the fact and estimate of amount of loss of water from leaf surface by weighing experiment.

Does water pass off both sides with equal rapidity? Determined by using filter paper impregnated by cobalt chloride.[1] Correlate with observations on the distribution of stomata.

Demonstration of transpiration by means of a bubble in a capillary tube.[2]

Respiration.

Recall the experiment demonstrating the need of oxygen by inhibition of growth of oat seedlings.

Demonstration of the production of carbon dioxide by the growing plant.[3]

Demonstration of passage of gases through stomata by displacement of air.

Photosynthesis.

Relation of starch formation to light as shown by applying the iodine test to etiolated and non-etiolated leaves.

[1] Take two leaves of the same kind with no free moisture upon them. Place one on a table dorsal side up, and the other vice versa, put a small square of perfectly dry cobalt paper on each; cover with a piece of glass and watch for the discoloration. The cobalt paper is made by dipping filter paper in a 10% solution of cobalt chloride and drying.

[2] MacDougal, D. T., *Experimental Plant Physiology*, Exp. 27, p. 23.

[3] Using barium hydrate as an indicator. The experiment outlined by Detmer-Moore (*Practical Plant Physiology*, p. 260) has been used and found very valuable. The simple and useful experiment of extinguishing a flame by inserting it into a volume of air in which seeds have been germinating is also used.

The effect of light upon chlorophyll; the action of a screen of leaf-red.

Leaves with specialized characters.

Arrangements for conserving water supply.

Thickened cuticle (e.g. Ficus).

Mucilage cells (e.g. Commelina).

Comparison of rate of wilting of a leaf of Commelina, and one of Fuchsia or Impatiens. Demonstration of mucilage cells in a transverse section. Notice mucilage on crushing the leaf between the fingers.

Reduction of transpiring surface.

Vertical position of leaves; phyllodes.

Leaves with water excreting glands (e.g. Fuchsia, Tropæolum).

Leaves with nectaries (Ricinus, Pteridium). Artificial nectary.

Leaves showing special mechanical adaptations (e.g. grass,[1] pine); as a clinging organ (e.g. pea).

The so-called carnivorous plants (e.g. Sarracenia, Nepenthes, Pinguicula, Drosera).

Insect traps (live cages) (e.g. Utricularia, Frullania, see beyond under Liverworts).

The ecology of leaf movements. Experimental study of leaf movements in Mimosa pudica.

The fall of the leaf.[2] Demonstration of prepared section.

Vegetative reproduction by means of the leaf (e.g. Bryophyllum, Begonia, certain ferns).

c. The bud.[3]

Review of structure of the embryo, especially regarding the plumule as a bud.

[1] For a discussion of the adaptive features of the grass leaf, see F. Le R. Sargent, *Corn Plants; their Uses and Ways of Life*, pp. 11-30.

[2] See in *Living Plants and Their Properties* the essay, "Leaves in Spring, Summer and Autumn," by D. T. MacDougal.

[3] The study of buds is postponed till the leaf has been studied. This is of considerable importance in order to the better understanding of the morphology of the bud, especially of those (e.g. Liriodendron or tulip tree) in which the stipules are used as protective organs.

Buds on stems of continuous growth.

The winter buds (hibernacula) of water weeds (e.g. Utricularia, Elodea, etc.).

The winter buds of perennial plants.

Structure of the bud; arrangement of the bud scales; waxy or resinous coatings.

Comparison of positions of leaf scars and bud-scale scars.

The part of the leaf to which the bud scale corresponds.

The storage of food substances in and near the bud. Apply proteid, starch and sugar test to a thick median longitudinal section.[1]

Buds as organs of reproduction (e.g. onion, bulbils of lily species).

II. A Study of the Types of the Groups of Plants

1. SPERMATOPHYTA: ANGIOSPERMS.

a. The willow.

The inflorescence: the axis (plumule) and the relative length of flower stalks (pedicel); position.

The flower: number, size and arrangement of the organs; dicœcism; diagram of staminate and pistillate flowers.

Ecology: adaptation to insect pollination; observation of the trees and insects at work (field work); dissemination; the origin of the pappus.

b. Hazel and alder; elm and maple. Using the willow as a type, compare it with these four with reference to

The inflorescence.

The structure of the flower; dicœcism and monœcism, floral diagrams.

Presence or absence of nectaries, the character of pollen (sticky or dry and powdery), character of the fruit and method of dissemination.

[1] It is important and valuable here to point out the analogy between the seed and the bud. A discussion of the subject will be found in the *Memoirs of the Torrey Botanical Club*, Vol. 2, No. 1, "Reserve Food Materials in Buds and Surrounding Parts," by Bryon D. Halsted, pp. 1-26, with 2 plates.

c. Calla lily (Richardia).[1]

Inflorescence: the thickened axis and shortened pedicels; crowding of the flowers.

The structure of the flowers.

Ecology: odor, adaptation for pollination, the rapid squeezing out of mature pollen, beautifully seen in this form.

Growth of pollen tubes.[2]

d. Hyacinth.

Inflorescence.

The flower: how many sets of organs, and their relative position? are they united or free? their relative position on the receptacle; diagram of transverse and longitudinal sections of the whole flower.

Method of pollination in the Liliaceæ of which this plant is a type. The odor, color.

e. Cypripedium.

The mechanism for effecting cross-pollination with the aid of insects is demonstrated by means of growing plants and prepared specimens.[3]

The homology of parts between the lily and orchid flowers is demonstrated.

f. Strelitzia (Iris).

The mechanism for pollination in these forms also is demonstrated by means of prepared specimens or living material.[4]

[1] Can be obtained at this time of the year from florists. The Jack-in-the-Pulpit (Arisæma) or golden-club (Orontium) can be obtained in the field now, or a little later.

[2] The production of pollen tubes is quite rapid in a 5% sugar solution. They are not favorable, however, for a study of the pollen tube structures.

[3] The flower in longitudinal section, and the various structures taken separately, may be displayed in a specimen jar affixed by means of gelatine to a piece of ordinary glass, and preserved in 5% formaline. The structures may then be examined from either side. See previous note.

[4] Special exotic forms, such as Strelitzia, are often difficult to get, although this form is common enough in glass houses. The writer has found that if specimens are obtained when opportunity offers and are properly preserved, much valuable material may be made available.

According to the same general plan of work as seen above the following forms have been studied. These particular forms are chosen on account of their availability, and may be supplanted by others, as circumstances permit or demand.

g. Buttercup.

h. Geranium.

i. Abutilon or Malvavistrum.

j. Some leguminous flower.

k. Azalea.

l. A cactus flower (demonstration).

m. Begonia.

n. Dandelion and field daisy.

2. GYMNOSPERMS.

The fir, spruce or pine.

The staminate and pistillate inflorescences.

Pollination.

The morphological meaning of the " fasicles " in pines.

The habit of these plants.

3. PTERIDOPHYTA.

a. Aspidium.[1]

Stem (rhizome) and leaf: their relative position.

Leaf (frond): examination of the venation, comparison of venation in several different forms to discover the points of resemblance and general character of fern venation.

Sorus: position of sorus with reference to veins; its form and position in various genera.

Indusium.

Sporangia and spores: movements of the sporangium under drying, and the scattering of the spores.

Prothallium (gametophyte). Germination of the spore

[1] In carrying on the work in ferns no particular type is adhered to, because some forms are more favorable for the study of certain points than others. For example, a pot of Polypodium is used for the demonstration of the rhizone.

and the development of the prothallium.[1] In a mature prothallium, find —

Rhizoids.

Antheridia,[2] and

Archegonia in surface view, under medium magnification.

The motile antherozoids[3] and the opening of the archegonia are demonstrated.

The developing fern plant (sporophyte) : examination of stages in development.

b. Equisetum.

Demonstration of different species by means of herbarium material.

Movements of spores by means of hygroscopic elaters.

Demonstration of prothallia.

The following types are demonstrated by means of museum preparations. Nothing more than an examination sufficient to get a general idea of the form of the plants is required. This is therefore done very briefly.

c. Isoetes.

d. Marsilia (venation).

e. Pillularia.

f. Salvinia.

g. Azolla.

Herbarium specimens of the following genera are exhibited. Additional points of study are noted.

[1] Demonstrated by means of charts, prepared specimens mounted in series (showing also the development of the sporophyte) and growing material.

[2] The student is greatly helped by seing a properly prepared longitudinal section of a mature prothallium.

[3] These can be obtained with ease if the prothallia, which must be mature, are kept for a day or two without being supplied with fluid water (by keeping them under a bell jar) and then subjecting them to a little more drying just before examination. They should be examined in water. Often the antherozoids will be caught in the rhizoids, and will then move about in a small area. They may then be examined with a higher power. If a good number are seen swimming about, the addition of a small drop of eosin-iodine, or simply iodine (in water with Potassium iodide) will kill them. They can then be examined more carefully, and the cilia, sac and spirals demonstrated.

h. Lycopodium.

Difference between foliage leaves and sporophylls.
Spores (all of one size).

i. Selaginella.

The two different sizes of spores.

At this point a brief sketch of the geological history of the pteridophyta is given, attention being called to the character of the vegetation of the coal period, and the nature and origin of coal.

4. BRYOPHYTA (the true mosses).

a. Polytrichum.[1]

Gametophyte. Compare its general character with those of the prothallium of the fern, as to the
Production of leaves; their position on the stem.
Stem.
Rhizoids.

Sporophyte. Its growth upon the gametophyte (compare with the fern), and its gross structure.
Seta, with the soft green foot embedded in the gametophyte.
Capsule, with its green tissue and hairy 'calyptra'; remove calyptra and note operculum, and, beneath it, the diaphragm.

In order that some of the more important features of mosses may be readily seen, the following types are used for the purpose of demonstrating the structure indicated.

b. Pogonatum: protonema: color of underground and above-ground parts.

c. Georgia (Tetraphis) pellucida: peristome of four teeth; gemmæ.

d. Funaria: Movements of the peristome.

5. HEPATICÆ (LIVERWORTS).

a. Radula.[2]

[1] Chosen for its size and ease of handling.

[2] Any foliose liverwort which produces sporophytes freely may replace this form. Cephalozia and Porella are two of these. The former may be found in moist place on decaying wood; the latter on the trunks of trees.

Gametophyte. Compare the leaves with those of Polytricum as to

(a) Arrangement on the stem;

(b) Relative complexity of structure, shape.

Sporophyte.

Insertion on the gametophyte.[1]

Seta; its weak, evanescent character, and its rapid growth after the maturity of the capsule is reached (compared with moss).

Capsule: absence of green tissue, method of dehiscence, elaters and spores. The remains of the neck of the archegonium. The calyptra at the base is seen to be a part of the gemetophyte. Compare with moss.

The following forms are examined with reference to the special points mentioned.

b. Frullania: adaptations of the leaves for holding water and minute animal forms.

c. Scapania:[2] gemmæ produced at the tips of the leaves (upper lobes).

d. Marchantia, and

e. Lunularia: the more obvious features of these two forms are briefly examined; more especial attention is given to the gemmæ.[3] Attention is called to the relative complexity of the gametophyte of the foliose and thallose kinds of Hepaticæ.

6. FUNGI.

The vegetative organs of the Fungi.

The physiological characters of Fungi:

Lack of chlorophyll.

[1] Demonstrated by sections and micro-photographs.

[2] Scapania grows on moist, shaded banks, and may be kept in the laboratory in good condition under a bell-jar all winter. So also may several others.

[3] Any greenhouse will afford materials of Marchantia and Lunularia. The latter is not to be found wild. Marchantia, on the other hand, is to be found rather easily, on moist clayey soil in open places. Young plants growing from gemmæ may be obtained readily, by sowing the gemmæ on soil under a bell-jar.

Saprophytism, parasitism, symbiosis, haustoria (see also above under mycorhiza).
Alternation of hosts.
Economic importance.
Types of Fungi as follows:

a. Agaricus.
Examination of a series of specimens of the edible mushroom showing:
The mycelium,
Developmental stages of the sporophore as whole objects and in longitudinal section.
The gills and spores.
Comparison of the three types of higher Basidiomycetes:
The gill-bearing, e.g. Agaricus,
The tooth-bearing, e.g. Hydnum,
The pore fungi, e.g. Polyporus.

b. Examination of
(a) Leaves infested with a rust (Puccina or Uromyces),
(b) Of the spores under magnification.

c. Morchella (edible morell).
Habit, gross features.
Asci, ascospores.

d. Sclerotinia: economic importance.
Demonstration of sporophores and sclerotia.

e. Lichens.
Examination of types of the more important biological groups, determining in each case the ascocarp.
Incrusting lichens of rocks and bark.
Foliaceous lichens of the ground and tree stems (Sticta, Peltigera).
Fruticose lichens: Usnea, Cetraria Islandica, Cladonia.
Microscopical examination of a gelatinous lichen (Collema) in order to demonstrate the algal symbiont.
Symbiosis in lichens.

f. Claviceps.
Habitat and poisonous qualities.

g. Cordyceps.
Habitat, external features.

h. Penicillium.
Examination of cultures.
Conidiophores and Conidia.

i. Microsphæra alni, the lilac mildew.
The fungus as it appears on the leaves of the host.
The perithecia, asci and ascospores.

j. Mucor.
General appearance of the plant as growing. Its habitat.
Mycelium: structure, absence of chlorophyll.
Sporangia and spores.
Demonstration of zygospores.

k. Saprolegnia.
The growing plant, habitat, source of food.
Mycelium.
Sporangia and spores.

l. Yeast.
Culture.
Microscopic appearance.

m. Algæ.
Spirogyra.
Structure of the plant.
Reproduction by means of zygospores.
Vaucheria.
Structure of the plant.
Sexual reproduction.
Demonstrations of various forms of the green, brown and red algæ.

n. Schizophyta.
Demonstrations of bacteria.
Cultures, natural and pure.
Microscopical preparations.
Fission algæ.
Oscillaria: form, movements.
Relation to quality of water supply.

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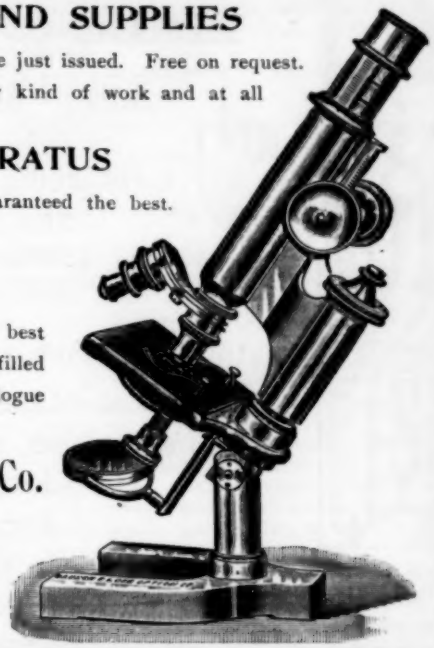

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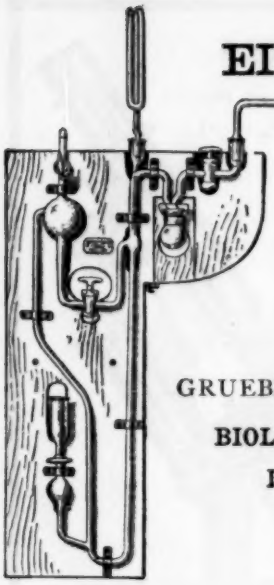

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5. TEACHERS COLLEGE, founded in 1888 and chartered in 1889, was included in the university in 1898. It offers the following courses of study: (*a*) graduate courses leading to the higher diploma or to the secondary diploma; (*b*) professional courses, each of two years, leading to diplomas for teachers and supervisors in kindergartens or elementary schools, or for specialists in Domestic Art, Domestic Science, Fine Arts, and Manual Training; (*c*) a collegiate course of two years, which, if followed by a two years' professional course, leads to the degree of Bachelor of Science. Certain of its courses may be taken, without extra charge, by students of the university in partial fulfilment of the requirements for the degrees of Bachelor of Arts, Master of Arts, and Doctor of Philosophy.

SETH LOW, LL.D., President.

Teachers College Record

CONTENTS OF VOLUME 1 — 1900

No. 1 January

The Function of the University in the Training of Teachers. — JAMES E. RUSSELL.

Historical Sketch of Teachers College from its Foundation to 1897. — WALTER L. HERVEY.

The Organization and Administration of Teachers College. — JAMES E. RUSSELL.

No. 2 March

Aims of Nature Study. — FRANCIS E. LLOYD.

Outline of Course in Nature Study in the Horace Mann School, etc. — ELIZABETH CARSS.

No. 3 May

Outline of Course in English in the Horace Mann School. — FRANKLIN T. BAKER.

English Composition and Topical Studies in Literature. — HERBERT V. ABBOTT, ELLEN Y. STEVENS, and EMILY V. BRINCKERHOFF.

No. 4 September

Syllabi for Teachers College Courses:

History of Education. — PAUL MONROE.

Principles of Education. — NICHOLAS MURRAY BUTLER.

School Administration. — SAMUEL T. DUTTON.

National Educational Systems. — JAMES E. RUSSELL.

No. 5 November

Outlines of Courses in Hand Work in the Horace Mann School:

Fine Arts. — ALFRED V. CHURCHILL.

Domestic Art. — MARY S. WOOLMAN.

Domestic Science. — HELEN KINNE.

Manual Training. — CHARLES R. RICHARDS.

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